621·39 : 621·33

Paper 41

Railway Telecommunication Cables and Equipment

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1 Introduction

The work of the railway telecommunications engineer is influenced in two ways by electrification. Firstly the effects of inductive interference must be taken into account both with respect to existing circuits and when planning new projects. Secondly, additional telephone facilities associated with electrification must be provided.

2 Electromagnetic Induction

Paper 9 by Dr. H. R. J. Klewe covers 'The Interference Problem' and consequently discussion of that subject will be limited herein to references to preventive measures taken on the telecommunications side and to matters arising therefrom.

Many telecommunications circuits on British Railways require D.C. transmission and preclude – or make complicated – the use of transformers for termination and sectionalising of cable pairs. Consequently the aim has been to maintain the longitudinally induced voltages within the C.C.I.T.T. limits of 60V and 430V for normal traction and shortcircuit conditions respectively. Some circuits requiring a D.C. path for signalling purposes have in fact been modified to enable A.C. signalling to be employed.

3 Choice of Cables

A description of the cables employed for the first three routes to be electrified at 50 c/s under the modernisation scheme namely Crewe – Manchester, Colchester – Clacton and Glasgow Suburban will suffice to illustrate the types of cables being installed on sections of British Railways where A.C. traction is being introduced.

Table 1 summarises the basic details of the cables and methods of obtaining adequate cable screening. All cables embody copper conductors and although only paper insulated air spaced cables are shown, polythene insulated quads will also be employed in the future. On main routes co-axial tubes will be provided for long distance trunk telephone circuits.

Armour tapes, where employed are cold rolled high permeability steel type EN2/A to the general requirements of British Standard Specification BS.1449 : 1948.

Cable sheaths and armouring are earthed every 1,000 yds. by means of earth beds comprising of a number of rods, in some cases driven to a depth of 80 ft.

4 Crewe – Manchester Route

It will be noted from Table 1 that, whereas some of the cables on the Crewe – Manchester route are provided with four armour tapes, other cables have only two tapes. This is due to the fact that it was necessary to have the cables installed in advance of the erection of the traction structures and, as a consequence, when it was necessary to put the cable on order, a decision had not been finally made to instal booster transformers in order to overcome interference with Post Office circuits. Estimation of the probable induced voltages without booster transformers showed that a cable screening factor of the order of 0·035 would be required for the voice frequency cables. With booster transformers two armour tapes will be adequate.

Two armour tapes were considered adequate for the carrier cables in any case because these cables could be suitably terminated and sectionalised by the use of transformers. Table 2 gives cable dimensions and the location of the various types of cable is shown in fig.1. The cables for this scheme were supplied by British Insulated Callendar Cable Co. Ltd.

Fig.2 shows the construction of the heaviest telecommunications cable employed on this route, namely the 104 pair.

TABLE 1. SUMMARY OF CABLE DATA

	Crewe – Manchester	*Colchester – Clacton*	*Glasgow Suburban*
Core … … … …	Star quad, air spaced paper insulated (conductor details given in Table 2)	Star quad, air spaced paper insulated (conductor details given in Table 3)	Star quad, air spaced paper insulated (Conductor details given in Table 4)
Sheath … … … …	Aluminium	Aluminium	Lead
Screening … … …	Tape armour over high conductivity sheath, earthed every 1,000 yards	High conductivity sheath earthed every 1,000 yards	Tape armour over lead sheath and copper screening wires earthed every 1,000 yards. (Copper screening wires not provided in largest cable)
Maximum longitudinal resistance of sheath (in parallel with any armour and screening wires)	0·25 ohms per 1,000 yards	0·25 ohms per 1,000 yards	0·6 ohms per 1,000 yards
Maximum resistance of each sheath earthing point	4 ohms	4 ohms	4 ohms
Bedding for armouring … …	2 × 0·01″ P.V.C. tapes Bituminous compound 0·02″ impregnated cotton tape	—	2 × 0·01″ P.V.C. tapes 0·02″ impregnated cotton tape compound
Armouring … … …	2 × 0·04″ mild steel tapes 0·04″ compounded hessian tapes 2 × 0·04″ mild steel tapes (only two steel tapes provided on the carrier cable and on the more recently ordered voice frequency cables)	—	Two mild steel tapes, each of thickness as follows:— 8 & 14-pr.—0·02″ 24 & 28-pr.—0·03″ 38 & 54-pr.—0·04″
Overall Protection … …	2 × 0·005″ P.V.C. tapes 2 × 0·025″ rubber tapes 0·005″ P.V.C. tape 0·04″ compounded hessian tape Graphite finish	Two extruded P.V.C. layers each 0·06″ thick	Compound 2 × 0·005″ P.V.C. tapes 2 × 0·025″ rubber tapes 0·005″ P.V.C. tape 0·04″ hessian tape Compound Whitewash

Between Crewe and Stafford a composite cable consisting of four co-axial tubes, four carrier quads (eight pairs) and eight pairs for repeater control purposes, together with one 54 pair local cable, is being utilised.

The diameter of the composite cable is about 3 inches.

TABLE 2. CREWE – MANCHESTER CABLES

Cable size	*Conductor size*	*Aluminium sheath thickness*	*Diameter over sheath*	*Overall Diameter With 4 steel tapes*	*Overall Diameter With 2 steel tapes*
14 pair (carrier cable)	36-lbs/ mile	0·060″	1·04″	—	1·87″
38 pair	40-lbs/ mile	0·060″	1·12″	2·21″	1·89″
54 pair	40-lbs/ mile	0·070″	1·31″	2·40″	2·07″
74 pair	40-lbs/ mile	0·080″	1·51″	2·62″	2·26″
104 pair	40-lbs/ mile	0·090″	1·76″	2·90″	2·51″

5 Colchester – Clacton Route

The traffic on the Colchester – Clacton line being appreciably less than that on the Crewe – Manchester line, the normal load and fault currents for the former could be assumed to be correspondingly less than for the latter. On this basis, and taking into account the employment of booster transformers with return conductors, it was considered that unarmoured aluminium sheathed cables would suffice. On short circuit test it was found that a voltage exceeding the limit of 430V could be induced longitudinally in the circuits which pass through the complete section Colchester – Clacton. However, the circuits have repeaters with suitable isolating transformers installed intermediately and thus the required limit is satisfied.

Fig.3 shows the cable layout and Table 3 gives details of the cables employed on this route. It will be noted that some of the cables are composite, being made up of quads with 40-lbs/mile and 70-lbs/mile conductors. The cables were supplied by Pirrelli-General Cable Works Ltd.

TABLE 3. COLCHESTER – CLACTON CABLES

Cable size	*Conductor size*	*Aluminium sheath thickness*	*Diameter over sheath*	*Overall diameter*
8 pair plus 12 pair	70-lbs/mile and 40-lbs/mile	0·059″	1·19″	1·43″
8 pair	40-lbs/mile	0·045″	0·66″	0·90″
24 pair	40-lbs/mile	0·051″	1·00″	1·24″
14 pair	40-lbs/mile	0·050″	0·80″	1·04″
6 pair	40-lbs/mile	0·045″	0·58″	0·82″
8 pair	70-lbs/mile	0·048″	0·79″	1·03″
6 pair	70-lbs/mile	0·048″	0·72″	0·96″
6 pair low capacity carrier plus 22 pair	36-lbs/mile and 40-lbs/mile	0·060″	1·15″	1·39″

6 Glasgow Suburban Route: Airdrie – Helensburgh

Details of the cables on this route, which were supplied by Standard Telephones & Cables Ltd, are given in Table 4, fig.4 being the route plan.

On this route booster transformers with return conductor are employed. As will be seen, the solution differs from that employed on the Colchester – Clacton route in that armoured cables are employed, but the allowable longitudinal resistance of the sheath path is higher on the Glasgow scheme.

TABLE 4. GLASGOW SUBURBAN CABLES

Conductor size: 40-*lbs/mile*

Cable size	*Number of 20-lb/mile copper conductivity wires below the sheath*	*Sheath Thickness*	*Diameter over Sheath*	*Overall Diameter*
8 pair	26	0·087″	0·76″	1·24″
14 pair	24	0·091″	0·90″	1·36″
24 pair	16	0·098″	1·08″	1·58″
28 pair	14	0·100″	1·13″	1·63″
38 pair	12	0·105″	1·26″	1·80″
54 pair	0	0·112″	1·37″	1·91″

7 The Effectiveness of the Cable Screening

The effectiveness of the preventive measures against induction is being verified on an overall basis by the Systems Tests Programme. The measurements so far made as part of this Programme have shown that induced voltages on the Colchester – Clacton route are well within the stipulated 60V during normal operation of the traction services, and with the through circuits split intermediately, short circuiting tests have demonstrated that the limit of 430V will not be exceeded under traction fault conditions. It must be remembered that the booster transformers provide an important measure of suppression – or at least reduction – of interference at source. Without booster transformers, the cable screening factors would require to be improved, but if considered purely on a cost basis it would fall to the railway telecommunications engineer to deal with the problem, suppression at source only being provided for experimental purposes or to satisfy the requirements of the Post Office.

Tests carried out on the Crewe – Manchester Line have indicated that the induced voltages when the section is completed will be well within the stipulated limits.

8 General Requirements in Connection with Equipment

The first requirement for equipment which is to be connected to lines exposed to induction is that a well balanced condition be maintained, thus minimising the introduction into the circuit of unwanted loop voltages and excessive voltages between pairs. This requirement of efficient balance should be observed under all conditions including signalling. The use of suitably designed transformers will enable good balance to be maintained and would also permit the higher voltage limits to be worked to, i.e. 60 per cent of the cable test voltage, should it be decided at any time in the future to work to limits exceeding the present maximum allowable voltages. However, the raising of the present limits to say 1200V would introduce maintenance difficulties and also the possibility of breakdown between cable pairs since circuits are of differing lengths resulting in voltage differences between pairs.

The use of transformers introduces difficulty when circuits requiring a D.C. path are involved. Use of coupled longitudinal choke devices have been considered as a possible means of protecting terminal apparatus from high induced voltages, but so far none has been used. However, in cases where transformers are employed and signalling pulses only have to be transmitted – apart from speech currents – the pulses can be passed round the transformers by means of special relay sets, or preferably the need for transmitting D.C. can be overcome by the use of A.C. signalling. Nevertheless there is much to be said for retaining standard D.C. signalling circuits, particularly those of the central battery type.

9 Circuits Carried by the Telecommunications Cables

Details of circuits carried by the telecommunications cables obviously vary somewhat from place to place, and thus a typical section of main line has been taken as an example for the purposes of this paper. It is asumed that there are three telecommunications cables, designated as follows:—

Cable No.1. Carrier Circuit Cable.
Cable No.2. Voice Frequency Cable.
Cable No.3. Local Cable.

The carrier cable employed so far has been standard low capacity with conductors of 36-lb/mile, but coaxial tubes will be utilised together with low capacitance quads for future main line routes. The present quad cables provide 12 both-way voice frequency circuits per pair, each channel having a band width from 300 to 3400 c/s. Most of these circuits form long distance trunk telephone circuits, but some voice frequency circuits will carry 18 or 24 channel voice frequency telegraph circuits.

The proposed coaxial tubes in the carrier cables will be utilised for the longer trunk circuits and will provide for data transmission and closed circuit television where these facilities become future requirements. The low capacitance quads will be required for the shorter distance trunk circuits.

The circuits listed in Tables 5 and 6 are typical of those carried in the voice frequency and local cables respectively. The latter cables are of course, also voice frequency cables.

It will be noted that the electric traction supervisory circuits are allowed for in both cables, thus providing standby arrangements should one cable become faulty.

Many of the circuits listed in Tables 5 and 6 call for little comment. The following sections give further details of some of the more interesting or novel items.

TABLE 5. SUMMARY OF CIRCUITS CARRIED BY THE VOICE FREQUENCY CABLE

Item No.	*Class of Circuit*	*Description*	*Remarks*
1	Exchange tie lines	Voice frequency telephone circuits with either 17 c/s ringing or central battery signalling or dialling	Eventually these circuits will become part of the nation wide automatic telephone system
2	Selective traffic control circuits	Voice frequency telephone circuits utilising coded pulses for selective calling	Existing circuits employ D.C. pulses or very low frequency but circuits have been modified to signal at 50 c/s and a new system employing 50 c/s pulses has been developed. (See Section 10)
3	Omnibus circuits	Voice frequency telephone circuits using either D.C. coded calling or D.C. loop dialling with revertive 50 c/s call	The D.C. coded call refers to the older systems. The 'revertive call' arrangement is a recently developed system. (See Section 11)
4	Exchange extension lines	Central battery circuits	Longer distance circuits would employ loaded pairs
5	Electrification telephone circuits	Voice frequency telephone circuits employing the recently developed A.C. selective system referred to in item 2 above	Loaded pairs in this cable are terminated by lengths of unloaded pairs in the local cable, the latter pairs serving as distribution lines to which the electrification telephones are connected
6	Voice frequency telegraph circuits	Voice frequency telegraphy	Loaded cable pairs utilised
7	D.C. telegraph circuits	Standard teleprinter circuits	Earth return circuits are not employed
8	Emergency block bell circuits	Direct current	Employed as stand-by for circuits in local cable
9	Block telephone circuits	Local battery telephones with magneto or battery ringing	—
10	Occupation crossing telephone circuits	Local battery telephones with magneto ringing	—
11	Supervisory pilot circuits for electric traction	Voice frequency signalling	Pairs are also provided in the local cable for these circuits. (See Paper 32)
12	Supervisory satellite circuits	Direct current	Pairs are also provided in the local cable for these circuits. (See Paper 32)
13	Common time circuit for synchronising station electric clocks	50 c/s impulses at $\frac{1}{2}$ minute intervals	Controlled by crystal chronometers
14	Telephone circuits to non-railway bodies, e.g. C.E.G.B.	—	Details of these circuits are subject to agreement between the bodies concerned and B.T.C.

TABLE 6. SUMMARY OF CIRCUITS CARRIED BY THE LOCAL CABLE

Item No.	*Class of Circuit*	*Description*	*Remarks*
1	Signal post telephone circuits	Central battery selective circuits	See Section 12
2	Electrification telephone circuits	—	See Table 5, item 5
3	Signal engineer's maintenance telephone circuits	(*a*) Local battery telephones with magneto call (*b*) Central battery plug in circuit connected to trackside locations	(*a*) Box to box circuits with up to six intermediate points (*b*) Circuits extending to limits of each signal box control area
4	Train describer (box to box) circuits	Coded D.C. pulses	—
5	Remote control of signalling circuits	Pulses of frequency between 25 and 40 kc/s. One frequency used for transmitting 'instructions' from 'parent' signal box and a different frequency employed to transmit back confirmation that the operation has been carried out	—

Item No.	Class of Circuit	Description	Remarks
6	Ground frame bell circuits	Direct current single stroke bells	—
7	Ground frame telephone circuits	Central battery telephones	—
8	Supervisory pilot circuits for electric traction	—	See Table 5, item 11
9	Supervisory satellite circuits	—	See Table 5, item 12
10	Supervisory satellite maintenance telephone circuits	Magneto telephone circuits from track sectioning cabins	—
11	Control and Tone input circuits in conjunction with loudspeaker equipment for staff location	Direct current and voice frequency circuits respectively	See Section 13

10 Traffic Control Telephone System

The selective telephones which were employed up to the time of A.C. electrification utilise direct current or $3\frac{1}{2}$ c/s for calling.

One well known system manufactured by Standard Telephones and Cables, Ltd, employs the transmission of digits giving a constant total in order to minimise the possibility of false calls. Calling may be either by rotary key one of which is provided on each control office desk for each outstation, or by dial. This system signals at $3\frac{1}{2}$ c/s, a frequency which unfortunately makes difficult the use of terminating and sectionalising transformers. However, signalling repeaters can be employed if a certain amount of sectionalising is required.

Another well tried system, manufactured by The General Electric Co. Ltd, employs direct current pulses. Calls are dialled and selection is effected by uniselectors. To enable line transformers to be employed the direct current pulses can be converted into pulses of 50 c/s current.

The Automatic Telephone and Electric Co. Ltd have developed a system based on the use of galvanometer relays. Two varieties of this system exist, one of which transmits alternating current pulses while the other employs direct current pulses. The dialling of the required outstation results in the transmission of pulses ranging between 1 and 12 impulses per second.

In the case of the A.C. system the pulses modulate the 50 c/s carrier frequency. At each outstation the pulses are applied, after rectification in the case of the A.C. system, to the galvanometer relay, which consists of a pair of magnets free to swing in the magnetic field generated by the pulses of signal current in the relay coil. The magnets oscillate under the influence of the signal pulses and in the case of the called outstation the oscillation builds up until a contact on the moving system closes with a fixed contact, resulting in the operation of the calling relay. The magnet system at each outstation is mechanically tuned to the impulse frequency employed to call that station. The A.C. system which will cater for 24 outstations is particularly suitable for circuits exposed to induction as it enables isolating and sectionalising transformers to be employed. Calling the control office from each outstation is effected by means of a buzzer generated tone. Fig.5 shows the basic circuitry of the system.

11 Omnibus Circuits

A new selective system which is being introduced, and can be employed in place of the code call omnibus circuit that relies on aural recognition of the code as reproduced by bell or buzzer, is a further development of the system made by Automatic Telephone & Electric Co. Ltd for control circuits and described in Section 10. As in the control circuit equipment, mechanically tuned relays are the basis of the system. Local battery telephones are employed and the line terminates on a register-generator. Each omnibus telephone transmits on a loop-dialling basis and the D.C. pulses are received by the register-generator which then transmits back over the line the necessary 50 c/s pulses to select the desired telephone. The equipment may terminate on a manual exchange, the operator being obtained by dialling the digit 'O'. Thus any omnibus telephone on the line will have access to any extension or trunk circuit on the exchange.

With further development the system will function in conjunction with an automatic exchange so that each omnibus telephone will have the same facilities as an ordinary extension on the exchange.

12 Signal Post Telephone System

The signal post telephone system manufactured by Standard Telephones & Cables, Ltd, provides the facility of calling from the signal post positions and giving the signalman a positive indication of the outstation from which the call is made. The engineman calls by turning a rotary key on the signal post telephone. If the line is disengaged, a bell in the signalbox will be caused to ring and the number of the calling signal location will appear on the lunar glass screen of the signalbox cabinet. The making of the call causes a reversal of potential in the circuit and locks out all other signal post telephone instruments thus preventing any other calls being made at the same time and ensuring secrecy.

If, when the key of a signal post telephone is operated, the circuit is engaged, an engaged lamp indicates this fact to the caller and remains illuminated until the circuit becomes disengaged when the caller may again operate his key.

The system is based on the constant total code referred to in Section 10.

13 Loudspeaker Equipment for Staff Location

A Staff location system being used is based on the use of loudspeakers, mounted back to back at $\frac{1}{2}$ mile intervals along the track for calling to the telephone three groups of maintenance personnel. Calling is by distinctive tones, as follows:—

(*a*) alternative two tone	(Group 1)
(*b*) triple tone	(Group 2)
(*c*) interrupted tone	(Group 3)
(*d*) continuous tone	(Cancellation)

Amplifiers with associated tone generators, each feeding a maximum of ten 5 watt loudspeakers, are distributed along the track and controlled from the parent signalbox using pairs in the screened telephone cable. The voice frequency pairs feeding the loudspeakers are of 1/0·064 in. twin P.C.P. insulated and sheathed cable. They are unscreened but lengths do not exceed $1\frac{1}{2}$ miles and isolating transformers are employed. The equipment was manufactured by Tannoy Products Ltd.

14 Conclusion

In conclusion it is appropriate to point out that much of the equipment mentioned in this Paper is by no means limited in its use to electrified areas. The use of carrier current telephony is well established and voice frequency telegraphy is expected to become increasingly important. Telephone exchanges have had only indirect reference but the important fact that they must present a balanced termination to any cable pairs passing through electrified areas has been mentioned in Section 8. This fact will have to be borne in mind when manual exchanges are renewed by automatic exchanges to make way for the national automatic telephone system which British Railways envisage.

Finally reference must be made to the all electronic telegraph centre being installed at Crewe. The equipment chosen is manufactured by Standard Telephone & Cables Ltd, namely STRAD, which is an electronic version of the torn tape relay system.

SUMMARY

This Paper gives details of the railway telecommunication cables on lines now being electrified, particularly with respect to the means of achieving satisfactory screening to reduce the effects of induction. Manchester – Crewe, Colchester – Clacton and the Glasgow Suburban routes are taken as examples of the use of three different types of cables.

The general requirements in connection with terminal equipment are briefly discussed and the use of circuits requiring the transmission of D.C. is touched upon.

The circuits likely to be carried by telecommunications cables along a typical section of electrified line are listed. Some of these circuits are required as part of the electrification scheme while others are independent of the traction system but are of interest because they have a bearing on the means taken to overcome the effects of inductive interference.

Special reference is made to traffic control circuits, omnibus circuits and signal post telephones, and a description is given of a loudspeaker system for staff location.

It concludes with brief reference to other telecommunications items including the electronic teleprinter switching centre for Crewe.

RÉSUMÉ

Cet exposé donne les détails des câbles de télécommunications des chemins de fer sur les lignes actuellement en électrification, particulièrement au point de vue d'obtention d'un effet compensateur pour réduire les effets d'induction. Les lignes Manchester – Crewe, Colchester – Clacton et la banlieue de Glasgow sont prises comme examples de l'emploi de trois types différents de câbles.

Les conditions générales relatives aux installations terminales sont discutées brièvement et l'emploi des circuits nécessitant la transmission du courant continu est traité.

Les circuits qui peuvent êtres composés de câbles de télécommunications sur une section typique de la ligne électrifiée sont énumérés. Quelques uns de ces circuits sont nécessaires comme faisant partie du projet d'électrification, tandis que d'autres sont indépendants du système de traction mais sont intéressants parce qu'ils se rapportent aux moyens utilisés pour vaincre les effets des perturbations d'induction.

On parle aussi des circuits de contrôle de trafic, des circuits omnibus et des téléphones de postes de signalisation. On décrit un système de hauts-parleurs pour contacter le personnel.

L'exposé se termine avec un bref rappel d'autres équipements de télécommunications comprenant aussi la centrale de commutation des téléimprimeurs de Crewe.

ZUSAMMENFASSUNG

Dieser Bericht gibt Einzelheiten von Eisenbahn-Fernmeldekabeln, die auf den jetzt elektrifizierten Linien verwendet werden, besonders mit Bezug auf die Massnahmen zur Erlangung einer ausreichenden Abschirmung und zur Verminderung der Induktionswirkungen. Die Strecken Manchester – Crewe, Colchester – Clacton und die Glasgow-Vorortslinien werden als Beispiele für die Anwendung von drei verschiedenen Arten von Kabeln angeführt.

Die allgemeinen Anforderungen im Zusammenhang mit den Endschaltungen werden kurz diskutiert und die Anwendung von Stromkreisen, in denen Gleichstrom fliessen muss, erwähnt.

Die Stromkreise, mit denen entlang eines typischen Abschnittes einer elektrifizierten Linie zu rechnen ist, sind in einer Liste aufgeführt. Einige dieser Stromkreise sind erforderlich als Teile des Elektrifizierungsplanes. Andere haben nicht unmittelbar mit der Elektrifizierung zu tun, sind jedoch interessant wegen der Mittel, die zum Schutz gegen Beeinflussung benutzt werden.

Auf die Verkehrs-Kontrollstromkreise, Omnibusleitungen und Signalmast-Telephone wird speziell verwiesen, ferner wird eine Beschreibung eines Lautsprechersystems für den Ruf von Streckenpersonal gegeben.

Der Bericht schliesst mit einem kurzen Hinweis auf andere Fernmelde-Einrichtungen, u.a. auf die elektronische Fernschreiber-Schaltzentrale für Crewe.

RESUMEN

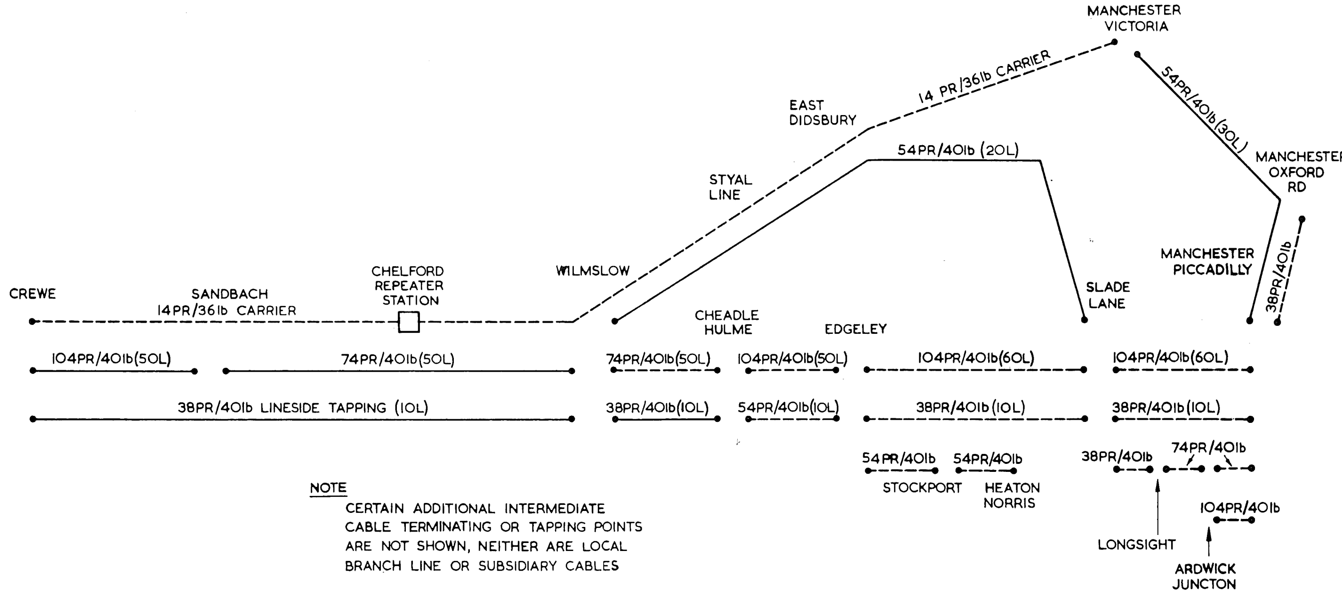
En este documento se facilitan pormenores acerca de los cables de telecomunicación ferroviaria en las línea que se están electrificando actualmente, particularmente en torno a los medios emple ados para conseguir un blindaje satisfactorio y reducir así el efecto de la inducción. Como ejemplos del uso de tres tipos diferentes de cable se citan las líneas de Manchester – Crewe, Colchester – Clacton y la red suburbana de Glasgow.

Se abordan, asimismo, los requisitos generales relacionados con el equipo terminal, que se describen someramente, y, se hace referencia al uso de circuitos que exigen la transmisión de corriente continua.

Se enumeran los circuitos que probablemente conduzcan los cables de telecomunicaciones a lo largo de una sección característica de la línea electrificada. Algunos de estos circuitos resultan indispensables como parte del sistema de electrificación mientras que otros nada tienen que ver con el sistema de tracción aunque revisten cierto interés por hallarse vinculados a los medios empleados para contrarrestar el efecto de la interferencia inductiva.

También se alude con especial atención a los circuitos de control de tráfico, circuitos auxiliares y teléfonos de poste de señalización y se describe un sistema de altoparlantes para la localización de los empleados.

Concluye refiriéndose sucintamente a otros equipos de telecomunicaciones, incluída la subestación teleimpresora electrónica de Crewe.



CONVENTIONS

74 PR/40 lb (5OL) = 74 PAIR 40lb CONDUCTOR A.S.P.I STAR QUAD ALUMINIUM SHEATHED CABLE WITH 50 PAIRS LOADED (88mH/2000yds) WITH 4 ARMOUR TAPES (40MIL) WITH Q2 R2 QH PROTECTION

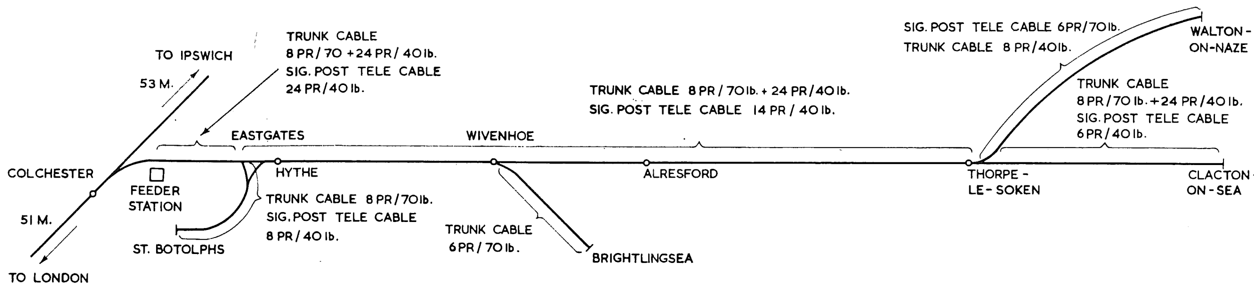
74 PR/40 lb (5OL) DITTO WITH 2 ARMOUR TAPES

Fig.1 Crewe – Manchester London Midland Region main telecommunication cables

Reference Table :

1. Long distance star quads
2. Belt papers
3. Lapped cotton tape
4. Aluminium sheath
5. P.V.C. Tape
6. Compounded cotton tape
7. Mild steel tapes
8. Compounded hessian
9. Rubber tape
10. Compounded hessian with graphite finish

Fig.2 64 pair steel tape armoured telephone cable employed on Crewe – Manchester electrification



SECTION OF ROUTE	TRUNK CABLE	SIGNAL POST TELE CABLE
COLCHESTER STN. M.D.F. TO FEEDER STN.	8 PR / 70 lb. + 24 PR / 40 lb.	14 PR / 40 lb.
COLCHESTER FEEDER STN. TO EASTGATES	8 PR / 70 lb. + 24 PR / 40 lb.	24 PR / 40 lb.
EASTGATES TO THORPE-LE-SOKEN	8 PR / 70 lb. + 24 PR / 40 lb.	8 PR / 40 lb.
THORPE-LE-SOKEN TO CLACTON-ON-SEA	8 PR / 70 lb. + 24 PR / 40 lb.	6 PR / 40 lb.
THORPE-LE-SOKEN TO WALTON	6 PR / 70 lb.	8 PR / 40 lb.
EASTGATES TO ST. BOTOLPHS	8 PR / 70 lb.	8 PR / 40 lb.
WIVENHOE TO BRIGHTLINGSEA	6 PR / 70 lb.	
51 MILE POST TO 53 MILE POST	6 PR / 36 lb. CARRIER + 22 PR / 40 lb.	

COLCHESTER-CLACTON TRUNK CABLE 8 PR / 70 lb + 24 PR / 40 lb - 24 LOADED PAIRS
WALTON BRANCH TRUNK CABLE 6 PR / 70 lb. - 6 LOADED PAIRS
ST. BOTOLPHS TRUNK CABLE 8 PR / 70 lb. - 8 LOADED PAIRS
SIGNAL POST CABLE COLCHESTER F.S. TO EASTGATES 24 PR / 40 lb. - 4 LOADED PAIRS
SIGNAL POST CABLE EASTGATES TO THORPE-LE-SOKEN 8 PR / 40 lb. - 4 LOADED PAIRS
SIGNAL POST CABLE WALTON BRANCH 8 PR / 40 lb. - 2 LOADED PAIRS

REMAINING CABLES ARE UNLOADED

Fig.3 Colchester – Clacton – Walton Eastern Region main telecommunication cables

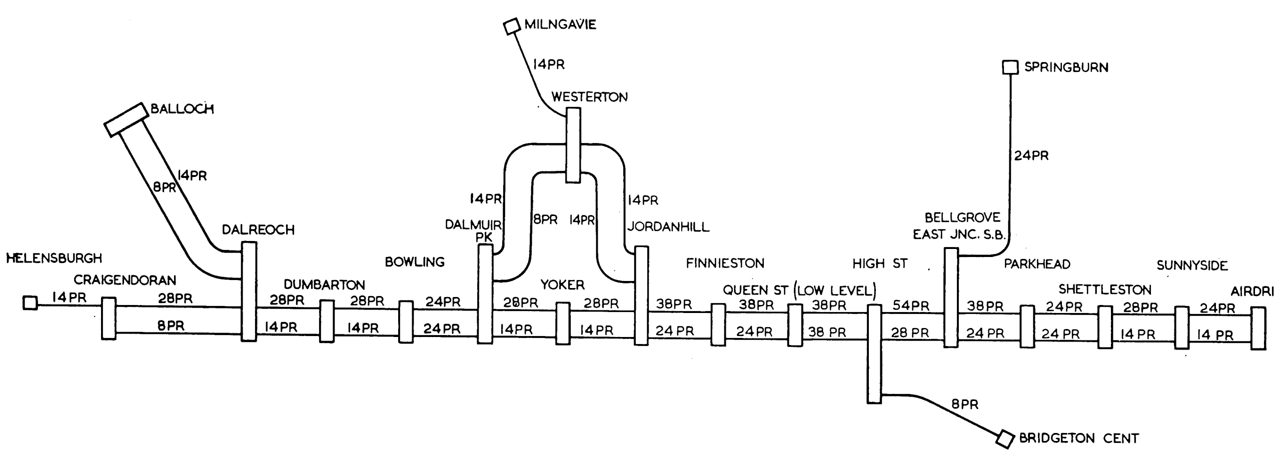


Fig.4 Glasgow Suburban electrification Scottish Region north of Clyde main telecommunication cables

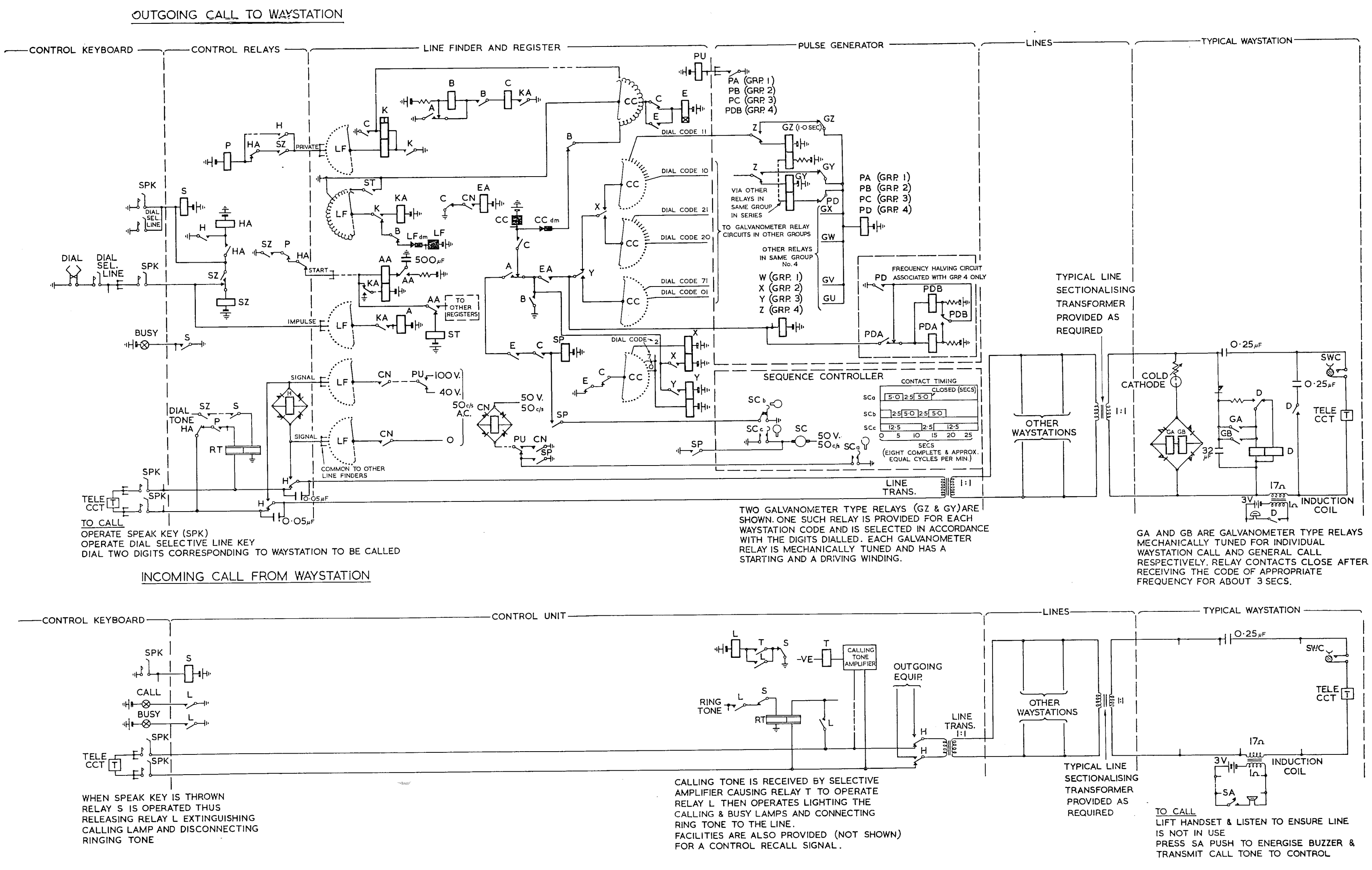


Fig.5 Outline of selective ringing omnibus circuit arranged for A.C. impulsing

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